Influence of Cone-Beam Computed Tomography Enhancement Filters on Diagnosis of Simulated External Root Resorption

Sergio Lins de Azevedo Vaz, DDS, Taruska Ventorini Vasconcelos, DDS, Frederico Sampaio Neves, DDS, MS, Deborah Queiroz de Freitas, DDS, MS, PhD, and Francisco Haiter-Neto, DDS, MS, PhD

Abstract

Introduction: The aim of this study was to determine if cone-beam computed tomography (CBCT) enhancement filters influence the diagnosis of simulated external root resorption (ERR). **Methods:** Buccal, mesial, and distal root surfaces of 20 single-rooted premolar teeth were evaluated for the presence or absence of simulated defects. Images were obtained using a Classic i-CAT CBCT device (Imaging Sciences International, Inc, Hatfield, PA) and analyzed by 3 oral radiologists. Evaluations were performed with and without CBCT filters. Accuracy, sensitivity, specificity, and positive and negative predictive values were determined. The McNemar test verified the disagreement between all images versus the gold standard and original images versus images with filters; P values < .05 were considered statistically significant. Inter- and intraobserver agreement was calculated by the kappa test. **Results:** The means of intra- and interobserver agreement ranged from good to excellent. Sharpen 3$\times$3 had the highest sensitivity (0.64), accuracy (0.62), and negative predictive value (0.33). Specificity was the highest (0.56) for S9, Smooth, Smooth 3$\times$3, and Angio Sharpen High filters. Positive predictive values were the highest (0.81) for the Smooth 3$\times$3 and Angio Sharpen High filters. The McNemar test showed statistically significant differences from the gold standard for all images (P < .05) as well as for original images versus images with the Shadow filter (P = .01). The other filters did not show statistically significant differences from the original images. **Conclusions:** The influence of enhancement CBCT filters on ERR diagnosis is small. The Sharpen 3$\times$3 filter gave the best results and the Shadow filter the worst results. *(J Endod 2012;38:305–308)*

Key Words

Cone-beam computed tomography, radiographic image enhancement, root resorption

From the Department of Oral Diagnosis, Division of Oral Radiology, Piracicaba Dental School, State University of Campinas, Piracicaba, São Paulo, Brazil.

Address requests for reprints to Dr Sergio Lins de Azevedo Vaz, Department of Oral Diagnosis, Piracicaba Dental School, State University of Campinas, UNICAMP, 901, Limeira Avenue, PO Box 52, 13414-903, Piracicaba, SP, Brazil. E-mail address: sergiolinsv@gmail.com

0099-2399/$ - see front matter

doi:10.1016/j.joen.2011.10.012

External root resorption (ERR) is characterized by the reduction in root length or the presence of defects on the root surface. Some causative factors are orthodontic movements, dental reimplantation, trauma, pressure resulting from the eruption of adjacent teeth, and pathologic conditions such as odontogenic and nonodontogenic tumors (1). ERR diagnosis is often based on clinical and radiographic examinations. Conventional radiographs can detect resorption only after 60% to 70% of the mineralized tissue had been lost (2). In addition, periapical radiography has limitations in determining which root surface is affected and how deeply.

Nowadays, cone-beam computed tomography (CBCT) scanning is widely applied in several areas of dentistry. The cost and exposure dose are lower than multislice computed tomography (3–5). The literature has already shown that CBCT is a good radiographic method for diagnosing ERR (6–11).

Filters are the tools of CBCT softwares designed to enhance images. They minimize image noise using mathematical algorithms to reduce or increase specific characteristics (12). The literature had already established the impact of filters on the radiographic diagnosis of some conditions such as dental caries (13–15), but there is a lack of studies about their influence on CBCT scanning. Therefore, the aim of this study was to determine if CBCT enhancement filters influence the diagnosis of simulated ERR.

Materials and Methods

After disinfection with 2% glutaraldehyde, 20 single-rooted premolar teeth extracted for orthodontic purposes were hydrated in water; no defects or root fractures were clinically visible. Cavities were randomly created at 9 regions of each root surface: buccal cervical, buccal middle, buccal apical, distal cervical, distal middle, distal apical, mesial cervical, mesial middle, and mesial apical. Four possible types of cavities were created: no cavity, a small cavity (0.26-mm diameter and 0.08-mm deep), a medium cavity (0.62-mm diameter and 0.19-mm deep), and a large cavity (1.05-mm diameter and 0.24-mm deep). The root surfaces received an equal number of defects totaling 60 buccal, 60 mesial, and 60 distal cavities. The defects were created with a spherical diamond bur (KG, Sorensen, Brazil) using a cavity preparation machine (16) to standardize the cavity diameter and depth. A gold standard was determined macroscopically after the defects were created on the roots.

The radicular portion of each tooth was uniformly covered with a 0.3-mm layer of utility wax (Epoxiglass, São Paulo, Brazil) to simulate the radiographic aspect of periodontal space and the alveolar cortical plate. Each tooth was put into stone-type plaster mixed with ground rice in equal ratio by volume. The presence of the wax layer reduces the artifacts around the root surface in the image (17).

Image acquisition was performed using Classic i-CAT CBCT (Imaging Sciences International, Inc, Hatfield, PA), operating at 120 kVp and 8 mA, an exposure time of 40 seconds, a field of view of 8 cm, and a voxel size of 0.125 mm. Under dim-light conditions, images were evaluated blindly by 3 previously calibrated oral radiologists with at least 1 year of experience on the Classic i-CAT CBCT device. All images were analyzed without filter application and with the use of the following filters for XoranCat software version 3.0.34 (Xoran Technologies, Ann Arbor, MI): Angio Sharpen Low, Angio Sharpen Medium, Angio Sharpen High, S9, Shadow, Sharpen, Sharpen 3×3, Sharpen Mild, Sharpen Super Mild, Smooth and Smooth 3 × 3 (Fig. 1). The images with Edge, Edge 3×3, Emboss, and Vertical Edges filters were completely unreadable and were excluded from this study.

The presence or absence of ERR was evaluated in each of the 9 regions of the root. Oral radiologists performed a dynamic evaluation using all slices and the zoom tool. The images were re-evaluated after 60 days. Inter- and intraobserver agreements were calculated by the kappa test (poor agreement, 0.40; moderate agreement, 0.40–0.59; good agreement, 0.60–0.74; and excellent agreement, 0.75–1.00).

The sensitivity (correctly identifying the presence of resorption), specificity (correctly identifying the absence of resorption), accuracy (proportion of correctness), positive predictive value (probability of true-positive result occurring), and negative predictive value (probability of false-negative result occurring) were calculated for each filter using SAS 9.1 software (SAS Institute, Cary, NC). The McNemar test was used to evaluate the agreement between all images versus the gold standard and the original images versus images with filters; $P < .05$ was considered statistically significant.

Results

Means of intra- and interobserver agreement ranged from good to excellent. Kappa values per filter are specified in Table 1. Sensitivity, specificity, accuracy, and positive and negative predictive values are shown in Table 2. The highest sensitivity (0.64), accuracy (0.62), and negative predictive value (0.33) were obtained for the Sharpen 3×3 filter. Specificity was the highest (0.56) for S9, Smooth, Smooth 3×3, and Angio Sharpen High filters. Positive predictive values were the highest (0.81) for the Smooth 3×3 and Angio Sharpen High filters.

The results of the McNemar test are presented in Table 2. The null hypothesis of agreement between images was rejected on comparing all

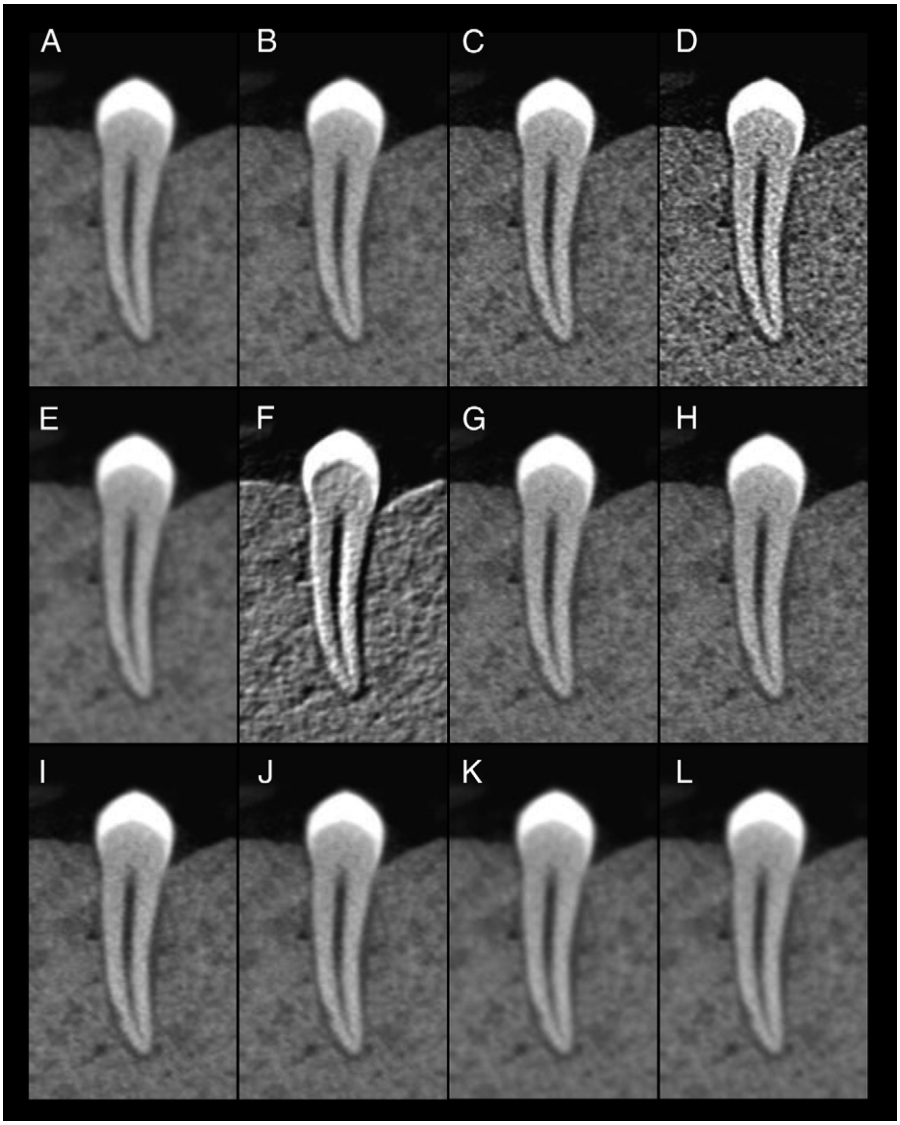

Figure 1. Coronal CBCT slices showing the simulated external root resorption with (*A*) no filter, (*B*) Angio Sharpen Low 3×3, (*C*) Angio Sharpen Medium 5×5, (*D*) Angio Sharpen High 5×5, (*E*) S9, (*F*) Shadow, (*G*) Sharpen, (*H*) Sharpen 3×3, (*I*) Sharpen Mild, (*J*) Sharpen Super Mild, (*K*) Smooth, and (*L*) Smooth 3×3.

TABLE 1. Means with Standard Deviations of Intraobserver and Interobserver Kappa Values per Filter

Filter	Intraobserver mean (SD)	Interobserver mean (SD)
No filter	0.60 (0.25)	0.61 (0.01)
Angio Sharpen Low 3×3	0.77 (0.14)	0.72 (0.03)
Angio Sharpen Medium 5×5	0.61 (0.31)	0.62 (0.09)
Angio Sharpen High 5×5	0.79 (0.07)	0.68 (0.03)
S9	0.78 (0.16)	0.64 (0.06)
Shadow	0.67 (0.09)	0.60 (0.08)
Sharpen	0.76 (0.19)	0.63 (0.06)
Sharpen 3×3	0.90 (0.03)	0.62 (0.08)
Sharpen Mild	0.75 (0.10)	0.63 (0.09)
Sharpen Super Mild	0.69 (0.31)	0.65 (0.05)
Smooth	0.67 (0.17)	0.68 (0.01)
Smooth 3×3	0.80 (0.06)	0.68 (0.01)

SD, standard deviation.

images versus the gold standard ($P < .05$) and images with no filters versus images with the Shadow filter ($P = .01$). There were no statistically significant differences between the other filters and the original images ($P > .05$).

Discussion

The purpose of this study was to evaluate if CBCT enhancement filters influence the diagnosis of simulated ERR. This is a common endodontic complication, and CBCT is an alternative for its detection and assessment. Studies have shown that the use of enhancement filters in digital radiography improves the diagnosis of caries lesions (13, 15). However, other studies have concluded that the diagnostic accuracy of occlusal caries and root fractures does not change with the application of filters (15, 18).

A study on the influence of enhancement filters on CBCT diagnosis evaluated the diagnostic accuracy of root fracture on images with filters (Angio Sharpen and Sharpen) and without (original images) (19). CBCT images with the Angio Sharpen filter had higher sensitivity (0.95) than images with the Sharpen filter (0.89) and original images (0.87). The authors concluded that this filter improved CBCT sensitivity. Although they studied root fracture, their tomographic parameters were very similar to those used in this investigation (i-Cat CBCT device with 0.125-mm voxel size), and the results showed better performance for Sharpen filters compared with original images. However, Angio Sharpen filters gave lower values that the Sharpen 3×3 filter on the present study.

On CBCT diagnosis of ERR, higher diagnostic values than those achieved in this investigation appear in the literature. We believe such results could be attributed to the small dimensions of the defects simulated in this study compared with others. In 1 study (7), the smallest defect was 0.6-mm wide and 0.3-mm deep and the largest was 1.8-mm wide and 0.9-mm deep, so their sensitivity value was about 0.97 applying a 0.2-mm voxel. In another study (20), 62.5% of small cavities (0.16-mm wide and 0.15-mm deep) and 87.5% of large cavities (0.3 mm) were diagnosed with a 0.125-mm voxel size. Only 1 study (8) had similar sized cavities to ours. Cavities were correctly identified in 77% of cases, and the absence of cavity was correctly identified in 53%. However, flat-panel volume computerized tomography with a smaller voxel size (0.07 mm) was used, so it is difficult to make a direct comparison.

Sensitivity, accuracy, and positive and negative predictive values presented low variation. The sensitivity and accuracy of the Shadow filter was the lowest; the Sharpen 3×3 filter gave the highest values. This can be explained because high-pass filters have good delineation of anatomic limits (21). Also, high-pass filters accentuate transitions in density levels because of mathematical recomputation of pixels (19). Because of this, we believe that ERR defects were highlighted with the Sharpen 3×3 filter, and the Shadow filter provided noisier images and less detail. The highest specificity values were obtained for the S9, Smooth, Smooth 3×3, and Angio Sharpen High filters. This can be justified by the fact that low-pass filters results in soft images with uniform gray scale (21), masking especially small cavities.

No statistically significant difference could be observed between original images and those with a filter applied, except for the Shadow filter, in agreement with other studies (15, 18). The Sharpen 3×3 filter enhanced the diagnostic values. These results are also in agreement with other studies (13, 14, 22). The Shadow filter presented a statistically significant difference from original images because its diagnostic values were the smallest. Thus, the Shadow filter gave images that were worse than images with no filter.

There are some limitations to an *in vitro* study in which only the imaging test is evaluated without considering clinical parameters such as pulp vitality, history of trauma, or orthodontic therapy, which can help in the diagnosis of ERR. Moreover, further studies with multiple-rooted teeth and other tomography devices are necessary.

In conclusion, the results of the present study suggest that using enhancement filters on CBCT images has little influence on ERR diagnosis. However, this study did note that the best results were obtained with the Sharpen 3×3 (not statistically significant) and the worst (statistically significant) with the Shadow filter.

TABLE 2. Diagnostic and McNemar Tests According to Different Filters

Filter	Sensitivity	Specificity	Accuracy	PPV	NPV	*P* value*	*P* value†
Original image	0.63	0.47	0.59	0.78	0.30	.005	–
Angio Sharpen Low 3×3	0.62	0.51	0.59	0.79	0.31	.0004	.45
Angio Sharpen Medium 5×5	0.63	0.42	0.58	0.77	0.28	.001	.83
Angio Sharpen High 5×5	0.62	0.56	0.61	0.81	0.32	.0004	.26
S9	0.61	0.56	0.59	0.80	0.32	.002	.11
Shadow	0.55	0.53	0.54	0.78	0.28	.0001	.01
Sharpen	0.63	0.44	0.58	0.77	0.29	.0056	1.00
Sharpen 3×3	0.64	0.53	0.62	0.80	0.33	.0017	.83
Sharpen Mild	0.61	0.51	0.58	0.79	0.30	.0005	.23
Sharpen Super Mild	0.63	0.51	0.61	0.80	0.32	.0111	.81
Smooth	0.61	0.56	0.59	0.80	0.32	.0002	.09
Smooth 3×3	0.62	0.56	0.61	0.81	0.32	.0003	.18

NPV, negative predictive value; PPV, positive predictive value.

**P* value of images versus gold-standard.

†*P* value of image filters versus original images.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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